Forefront Science Aims to Meet Environmental Grand Challenges

Motivation

Global economic development to improve the quality of life for a growing human population intensifies stresses on the biosphere and ecosystems. Our future prosperity depends on understanding complex environmental systems so that we can respond successfully to environmental changes and threats. Gaining this understanding requires integrated knowledge from all branches of science.

Approach

Argonne's Grand Challenges in Environmental Science initiative is designed to harness forefront research in traditional disciplines to address the most important questions facing environmental scientists today. Argonne's current capabilities, coupled with recent developments in science and technology, offer the potential for major breakthroughs in the areas of

- Natural controls and perturbations in biogeochemical cycling,
- Global and regional effects of atmospheric particulates and aerosols, and
- Consequences of a transition from a hydrocarbon-based economy to one based on hydrogen.

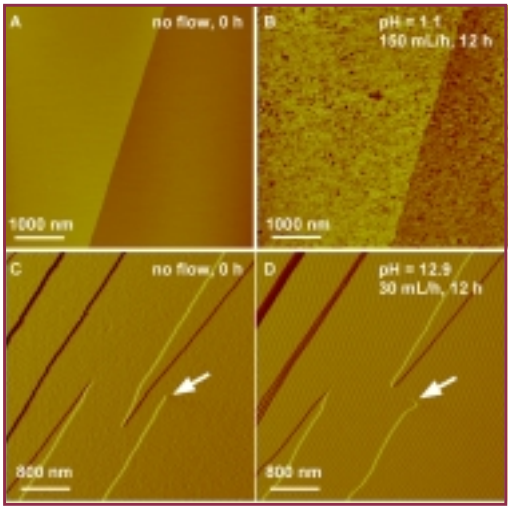

Figure 1. Weathering of the mineral orthoclase, as studied with atomic force microscopy and x-ray reflectivity. Weathering occurs layer by layer, and reactive sites are distinct at extreme pH values.

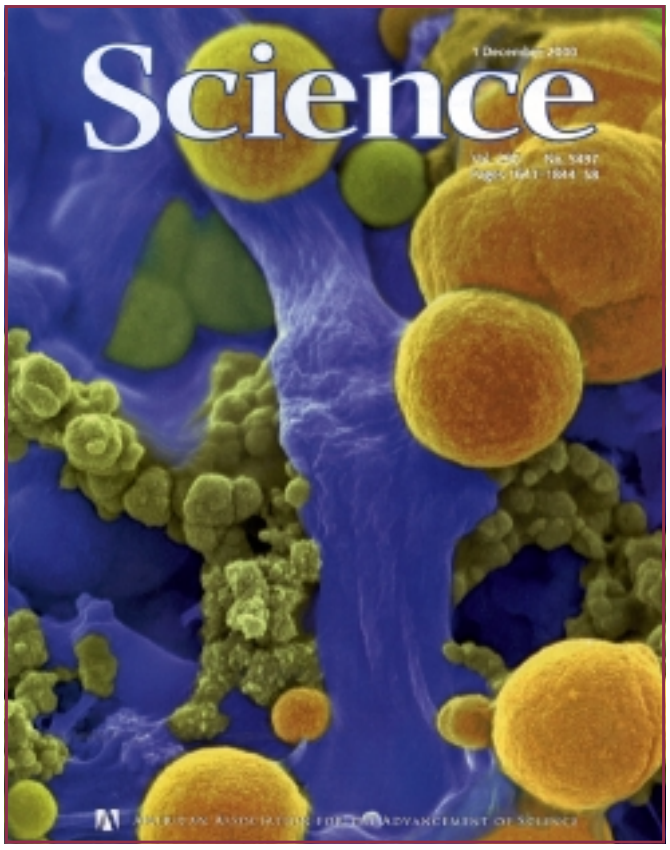

Figure 2. Mineralization in biofilms in an abandoned mine, as studied with x-ray and electron microprobes. The incorporation of arsenic and selenium into the zinc ore suggests that nanosized ZnS (sphalerite) particles could be used to remediate metals contamination. (Reprinted with permission from Science, *Volume 290, No. 5497, Copyright 2000, American Association for the Advancement of Science.)*

First, to meet the biogeochemistry challenge, Argonne seeks to determine the mechanisms controlling transfer of compounds to and from storage reservoirs, as well as to quantify the rates of accumulation and depletion. In collaborative studies using synchrotron radiation, researchers have already revealed layer-by-layer chemical weathering of the mineral orthoclase (Figure 1) and shown that microbes play a key role in the formation of mineral deposits and the potential sequestration of metal contaminants (Figure 2).

Figure 3. Urban industrial air pollution over Albuquerque, New Mexico.

Atmospheric particulates, both natural and man-made, result from energy production and use. Such particles are harmful to human health, play a major role in acid rain formation, and have atmospheric cooling effects as large as the heating effects of greenhouse gases. The transport of atmospheric particles over long distances affects national security (e.g., transport of harmful spores) and general air quality (through atmospheric chemical interactions; Figure 3). Argonne plans to address this second challenge by determining how atmospheric particles are formed, their roles in global and regional climate systems, and their relevance to chronic and acute respiratory diseases.

Advances in fuel cells and new methods for efficiently manufacturing hydrogen are key factors in a shift to a hydrogen economy. Argonne is both developing the requisite technologies for such a shift and addressing the environmental consequences. Coupled with fuel cell power, the Laboratory's strong programs in hydrogen production from gasoline, diesel fuel, and other hydrocarbons promise much more efficient use of these fuels in transportation applications (Figure 4). Argonne is also exploring hydrogen production with nuclear heat as the energy source. These studies are aimed at developing a more efficient, cleaner product, and they take advantage of Argonne's strong engineering capabilities and novel approaches to environmental control technologies.

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Figure 4. Argonne's catalytic fuel processor or "reformer," which extracts hydrogen from liquid hydrocarbons.

Potential Sponsors and Collaborators

Argonne's Grand Challenges in Environmental Science initiative is a pioneering approach to multidisciplinary integrated research. The work fits within the scope of the U.S. Global Change Research Program's FY2003 initiative in climate change, a likely near-term source of funding. Other potential sponsors are

- U.S. Department of Energy (DOE's) Genomes to Life Program,
- DOE environmental remediation studies (such as the Natural and Accelerated Bioremediation Research Program and the Environmental Management Science Program),
- Environmental Protection Agency,
- National Oceanic and Atmospheric Administration,
- National Aeronautics and Space Administration,
- National Science Foundation (in collaboration with university partners), and
- U.S. Department of Defense.

Grand Challenges in Environmental Science will draw on the resources of the new Joint Argonne-University of Chicago Center for Environmental Science, a formal collaboration for research on environmental issues.